Sustainability assessment for the production of bio-based products using by-product streams derived from the pulp and paper industry

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Keywords: life cycle assessment, techno-economic evaluation, integrated biorefineries
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Biomass is a sustainable diversified renewable resource sufficient to replace to a great extent finite fossil fuels covering, among others, the rising human needs for food, feed, energy, chemicals and fuels. Within the last decade, production of bio-based chemicals has attracted increasing interest from academia and industry as societies endeavor to swift to a less petroleum-dependent economy. Waste valorization turns to be a crucial factor for the creation and development of future sustainable biorefineries as they provide inexpensive organic feedstock to be used directly or after pretreatment as feedstock in microbial fermentations. An important lignocellulosic by-product stream is produced in vast amounts by the sulphite pulping process of wood, known as spent sulphite liquor. This by-product contains lignosulphonates and various C5 and C6 sugars derived from the hydrolysis of hemicellulose during the digestion of wood chips. The high content of sugar monomers indicates that this by-product stream could be used as fermentation feedstock for chemical production.

In this study, the sustainability of an integrated biorefinery for the production of succinic acid, lignosulphonates and phenolic-rich extracts from spent sulphite liquor has been evaluated. A techno-economic evaluation was performed by designing all the critical unit operations involved in the process starting from the pretreatment of the raw material and the extraction of phenolic compounds and lignosulphonates to the fermentation process and recovery of platform chemicals such as succinic acid. Different process flowsheets based on literature-cited studies and experimental data were subsequently developed and compared in order to identify cost-competitive downstream separation and purification processes in the case of succinic acid production. The net present value of the developed processes was assessed for different plant capacities. A detailed life-cycle assessment (LCA) was also carried out for the developed processes considering different production capacities. A Life Cycle Inventory was prepared. This LCA study included all important steps in the life cycle of the obtained end-products taking into consideration the energy and mass inputs as well as the greenhouse gas emissions and waste streams produced from each process/unit operation. The LCA served as a mean to identify the unit operations where process optimization could result in significant environmental benefits. Finally, the LCA was combined with the techno-economic assessment in order to develop processes that minimize waste production and greenhouse gas emissions and at the same time are cost-competitive.

Acknowledgments: This work is funded by the FP7 research project entitled "*New tailor-made biopolymers produced from lignocellulosic sugars waste for highly demanding fire-resistant applications*" (Acronym: BRIGIT, Grant agreement no: 311935).